22 FEBRUARY 1980   (FOUO 1/80)

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JPRS L/8944

22 February 1980

USSR Report

INDUSTRIAL AFFAIRS

. (FOUO 1/80)

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USSR REPORT

INDUSTRIAL AFFAIRS

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AUTOMOTIVE AND TRACTOR INDUSTRY

SERVICE LIFE OF SPARE PARTS

Alma-Ata AVTOMOBIL'NYY TRANSPORT KAZAKHSTANA in Russian No 4, 1979 pp 38, 39, 44

[Article: "Spare Parts"]

[Text] It is important for every car owner to know which of his car's parts and assemblies may need replacement, and also he should know what he should keep on hand to feel confident on a long trip. It is also useful to know the utilization possibilities of parts and assemblies and their interchangeability with parts and assemblies from other Soviet-made automobiles.

Our experience enables us to predict in an approximate manner the service life (in kilometers or years) of automotive parts on the basis of natural wear and tear. As regards component units as a whole -- motor, clutch, transmission, driveshaft, differential, steering gear, front and rear suspension, and brake system -- their service life, with proper servicing, will exceed 100,000 kilometers. The figures contained in Table 1 apply to year-round auto use, primarily on paved roads, with approximately 60% of total mileage city driving and approximately 40% highway mileage. The figures apply to a temperate climate zone and moderately broken terrain. In all other cases -- when an auto is operated primarily off hard-surface roads, in cold and hot climate, in mountain terrain -- the service life of parts, assemblies and component units, as well as the car as a whole will be less. In addition, these figures do not take into consideration the possibility of premature failure of certain parts, an occurrence which, however, is rare if a car is treated properly.

The service life of the majority of other parts and assemblies with natural wear and tear usually exceeds 100,000 kilometers.

In spite of the overall high reliability of Zhiguli automobiles, it is desirable to carry in the car, especially on long trips, a number of spare parts, supplementary tools and accessories. In addition, in conformity with current requirements, each car should be equipped with safety belts (at least for the driver and front-seat passenger), first aid kit, marker to alert other motorists of a stopped car, and a fire extinguisher.

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Table 1. Approximate Service Life of Certain Parts and Assemblies

Part or Assembly	Expected Service Life, thousand km	Comments
Camshaft	More than 80	In vehicles built after June 1973
Valve rocker arms	More than 80	Same
Carburator needle valve	50-70	
Throttle linkage	70-90	
Clutch driven plate	60-80	Depending on driver's habits
Drive shaft universal joint, in assembly with needle bearings	80-100 (front) 50-70 (rear)	
Steering gear tie rod ends	80 and more	If worn covers are promptly replaced
Upper and lower ball joints	100 and more	For cars built after December 1971, assuming periodic lubrication and prompt replacement of worn covers
Window raiser, left front door	40-50	
Window raiser, right front foor	60-70	
Pendulum lever inserts and shaft	60-80	
Front brake shoes	12-30	
Hood latch cable	20-30	
Rear brake shoes	80 or more	
Front shock absorbers	30-100	
Rear shock absorbers	40-100	
Lower inserts of front shock absorbers	20-30	
Rear shock inserts	80-100	
Tires (to allowable tread wear):		Depends on driving habits
I-51, 6.45 x 13 (165-330)	35-40	
M-130A, 6.15 x 13 (155-330)	40-45	
IYa-170, 165-13R	60-70	
Battery	3-4 years	Depending on manufacturer
Spark plugs	30-40	
Distributor points	70-90	

The models 210J, 2102, 2103, 2106, and 21011 VAZ cars are standardized to a substantial degree, while this applies to a lesser degree to the VAZ-2121. This applies in particular to the majority of relatively rapidly-wearing parts and assemblies listed in Table 1. Nevertheless there are certain specific features here.

VAZ cars (other than the 2121) are assembled at the factory with two different wheel rims (differing in width) and four different tires; the figures are contained in Table 2.

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One must know the following information when changing wheels and tires:

    all tire sizes can be mounted on the "wide" rim; 6.15 x 13, 155-13R and 6.45 x 13 tires can be mounted on the "narrow" rim; it is possible but undesirable to mount 165-13R tires;

    any of these four tire sizes can be mounted on VAZ-2101 and VAZ-21011 cars; 6.45 x 13 and 165-13R tires can be mounted on VAZ-2102, VAZ-2103, and VAZ-2106 cars;

    it is desirable that identical tires be mounted on all wheels; it is permissible to mount different tires on the front wheels from those on the rear wheels; different tires should not be mounted on the left and right wheel of the same axle.

The tubes of all the above-listed tires are interchangeable. In addition, experience has shown that one can also use Moskvich-408 and 412 tire tubes; until recently, however, these tubes had a thicker rubber valve stem facing, which requires increasing the size of the valve stem hole when used with Zhiguli rims; hole enlargement does not prevent subsequent use of these rims with standard tubes.

VAZ-2121 rims and tires have a fit size of 16 dm, because of which they are not interchangeable with the rims and tires of other VAZ models.

One must bear in mind that tubes for Zhiguli tires are manufactured of butyl rubber; because of this, punctures in these tubes cannot be sealed by applying cold patches (without hot vulcanization).

The rear brake shoes on VAZ-2103 and VAZ-2106 automobiles have devices which automatically adjust shoe-drum clearance, and therefore they are not interchangeable with the rear brake shoes of VAZ-2101, 2102, and 21011 models.

The cylindrical rubber lower inserts of the front shock absorbers and conical inserts of the rear shock absorbers are identical in design on all VAZ models; the rear shock absorber conical inserts are interchangeable with the shock absorber conical inserts of all Moskvich models (other than 400 and 401), Volga and Zaporozhets. If one does not have spare front shock absorber cylindrical inserts, conical inserts can be used, which requires trimming from the wide end so that they enter the shock absorber arm with a tight fit.

All VAZ models are equipped at the factory with A7.5 BS, A7.5 KhS spark plugs or spark plugs of GDR manufacture; these plugs have a longer threaded section than the plugs employed by the majority of other Soviet-made cars. All plugs are interchangeable. Plugs of different (listed above) makes can if necessary be installed on different cylinders of the same motor. Zhiguli motors will also operate satisfactorily with the A7.5 SS plugs used on the Moskvich-412. In an emergency one may temporarily employ the 14 mm plugs with a shorter threaded section from model 402, 403, 407 and

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408 Moskvich, GAZ-21 and 24, as well as from GAZ-53A and ZIL-130 trucks; this is undesirable, however, because these plugs will operate less dependably, and replacement with the longer-thread plugs may prove difficult, since the exposed threads below the plugs may become fouled with carbon (if this happens, prior to installing an extended-thread plug it will be necessary to run a tap down the threads, and this can result in metal shavings entering the cylinder and scoring the cylinder wall).

Table 2. Rims and Tires for VAZ Automobiles

Rim and Tire	Designation and Size	VAZ-2101, VAZ-21011	VAZ-2102	VAZ-2103 VAZ-2106
"Narrow" rim	114-330 (4 1/2-13)	+	+ or +	+
"Wide" rim	127-330 (4-13)			
Bias-ply tire	6.15 x 13 (155-13)	+ or +		
Radial tire	115-13R			
Bias-ply tire	6.45 x 13 (165-33)		+ or +	+
Radial tire	165-13R			

Corresponding plugs of foreign manufacture may be used, but it is useful to know that they do not offer any advantages over Soviet-made plugs.

The ignition coils employed in the VAZ models are interchangeable (except for the Moskvich-400 and 401, which are for a 6 volt system).

Condensers are interchangeable with any other automotive ignition condensers.

Sample List of Spare Parts Carried in an Automobile

Spark plugs (2); breaker points; distributor rotor; condenser; distributor cap; high voltage wire caps (2); carburator diaphragm; carburator needle valve and gasket; spare headlight bulb; two-filament parking light and brake light bulbs (2); single-filament rear turn indicator bulb (can be replaced by bulb from portable lamp); license plate illuminating bulb (can be replaced by hood light bulb); turn signal bulb (can be replaced by trunk light bulb); fuses (3); fan belt; tire valve caps (2); tire valve cores (2); high-voltage ignition wire (1 meter); low-voltage wire (5 meters).

Sample List of Supplementary Tools and Accessories Carried in a Car

9 x 11 wrench; 12 x 14 wrench; hammer; tire iron; small slot-head screwdriver; small Phillips-head screwdriver; set of socket wrenches (small); awl; round file; scissors; flat file; jackknife; circuit tester (portable lamp with leads and terminal clips); electric vulcanizer with uncured rubber;

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chalk (one piece); tire pump with pressure gauge; set of bolts, nuts,
washers and cotter pins; tire tube rubber (one piece); baling wire
(2 meters); friction tape; flashlight; tow cable (preferably flexible);
gas can (20 liter); funnel with filter for transferring gasoline; clean
rag; plastic bucket; sponge; jumper cables (for winter);

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METALWORKING EQUIPMENT

WEST GERMAN INDUSTRIAL ROBOTS

Moscow STANKI I INSTRUMENT in Russian No 10, Oct 79 pp 24-25

[Article by Yu. G. Kozyrev]

[Text] Industrial robots (IR) have been used in West Germany machine
building since 1970. In late 1978 the overall machine pool of the nation
contained more than 350 robots (the average annual increment was 30 IR). By
the end of 1980 the number of IR of various technological purposes will
exceed 500 units [1]. The expansion of the IR pool is illustrated in
Figure 1a; the course of adoption of new IR in West German industry is
illustrated in Figure 1b. The machine pool is made up of national robots
and of robots imported from the United States, Japan, Norway and other
countries.

A histogram of the distribution of IR among sectors of the machine building
industry (Figure 2) shows that robots are used most extensively in the
automobile industry. A histogram of the distribution of IR among operations
that are performed (Figure 3) shows that most of the IR are used for per-
forming lifting and transport operations, for charging machinery and for
welding. The histograms are based on data as of the end of 1977.

The nomenclature of IR is quite diverse: from the simplest EKOMAT (or
FELSOMAT) types to multiprogrammable general purpose IR (called universal)
of the Unimate type.

The performance characteristics of the basic models of IR, used in West
German industry (as of the end of March 1978) are presented in the table.

Cost varies from robot to robot. It is interesting to analyze cost
associated with their industrial adoption [1]. The cost of the industrial
adoption (spray painting) of a model IRB 6 robot, which is priced at 185,000
marks, was 15,000 marks (8% of the cost of the machine). Based on data of
the manufacturer, the purchase price and cost of adoption were recovered in
3 years. The adoption cost of a Unimate IR was 15,000-165,000 marks
(14-143% of the cost of the robot). The industrial adoption of a single
robot is most expensive, and the installation of several robots in shops is

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the least costly (per robot). The overall cost depends also on the type
of technological process and the machinery automated with the aid of IR.
It has been shown [1] that the development of complexes for servicing
glass-casting machines (up to 165,000 marks) and hot stamping presses (up
to 125,000 marks) accounts for most of the adoption cost of robots of the
Unimate type, and the adoption of a "pressure casting machine-fettling
press" complex -- the least.

Thus, the adoption of IR always involves additional costs of mating with
machinery, replanning of industrial facilities, organization of production,
etc., and the fraction of these costs per robot depends on the number of
industrially adopted "machine-robot" units and on the type of technological
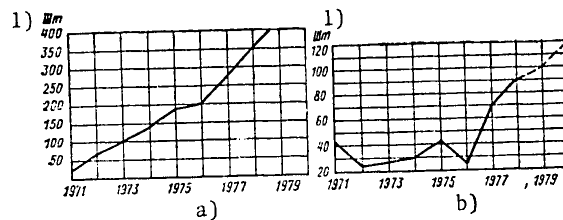process and machinery, mated with the robot.

Figure 1. Growth of inventory (a) and course of adoption
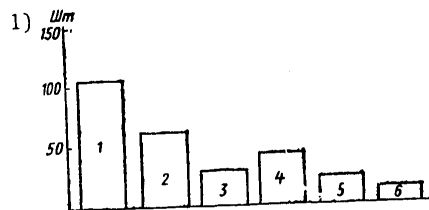(b) of IR in West German machine building.
KEY: 1. Units

Figure 2. Distribution of IR among sectors of
machine building: 1 -- automobile industry;
2 -- general machine building; 3 -- household
appliances; 4 -- sanitary engineering; 5 --
electrical engineering; 6 -- miscellaneous.
KEY: 1. Units

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2) Фирма-изгото-витель или поставщик	3) Модель робота	1) Основные техниче-ские данные			7) Стои-мость од-ного ЗР, тыс. ма-рок	8) Число изготовлен-ных ПР
		4) Грузоподъ-емность, кг	5) Точность позицио-нирова-ния, мм	6) Число сте-пеней под-вижности		
ASEA (Швеция9)	IRB 6 IRB 60	6 60	±0.2 ±0.4	6 6	150—185 150—225	9 4
Robert Bosch GmbH (ФРГ)10)	MHV-senior MHV-junior	15 5	±0.1 ±0.1	5 6	60 42	13 2
Devilbiss (Англия-ФРГ-Норвегии)11)	TR 2000 TR 3000	— —	±5.0 ±3.0	5 6	— —	48 21
Коммерческое представитель-ство IWKA (ФРГ, Япония и др.) 12)	1310 1320 4/150 4/25 6/60 4500 AH 3 PM 12 Koordinaten-maschine	10 10 80 10 60 10 3 10 200	±1.0 ±1.0 ±0.5 ±1.0 ±1.5 ±0.25 ±0.1 ±1.0 ±0.2	5 5 4 4 6 5 4 5 4	75—100 75—100 — 250 — 150—230 — 70—100 —	12 3 1 1 2 6 11 2 13
Rhein—Nadel Automation GmbH (ФРГ)10)	ZE 6075 Varlomat	1 0,5	±0.6 ±0.1	6 3	—	1 5
Unimation Inc (США) 13)	Unimate 2000 Unimate 2005 Unimate 2100 Unimate 4000	15 15 15 75	±1.27 ±0.5 ±1.27 ±2.0	6 6 6 6	82—140 150 90—110 140—160	30 1 24 6
VFW—Fokker GmbH (ФРГ) 10)	Transferauto-mat L Transferauto-mat E Sonderkonst-rukt	3 20 15	±0.1 ±1.0 ±0.1	1 3—4 2	20—22 85—95 40	3 12 1
Volkswagenwerk AG (ФРГ)10)	L15 K15 R30 R100	15 15 30 100	±2.5 ±1.0 ±1.0 ±2.5	3 5 6 5	—	7 2 6 2
Zahnradfabrik Friedrichshafen AG (ФРГ)10)	ZF Bankasten Automater	20 35	±0.2 ±1.0	3 5	70—80 90—140	3 3

14) Всего 257

KEY:
1. Basic technical specifications
2. Manufacturer or supplier
3. Robot model
4. Lifting capacity, kg
5. Positioning precision, mm
6. Number of degrees of mobility
7. Cost of one IR, in thousands of marks
8. Number of IR manufactured
9. (Sweden)
10. (FRG)
11. (Great Britain-FRG-Norway)
12. Commercial representative of IWKA (FRG, Japan, etc.)
13. (United States)
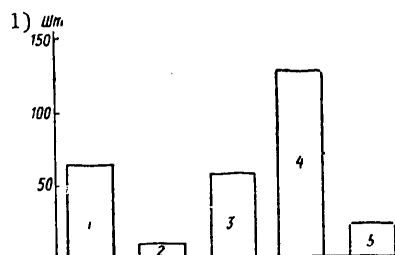14. Total

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Figure 3. Distribution of IR by character of operations performed: 1 -- charging of processing machinery; 2 -- servicing of pressure casting machines; 3 -- welding; 4 -- lifting-transport operations; 5 -- miscellaneous.
KEY: 1. Units

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METALWORKING EQUIPMENT

POLISH INDUSTRIAL ROBOTS

Moscow STANKI I INSTRUMENT in Russian No 10, Oct 79 pp 25-27

[Article by V. B. Velikovich]

[Text] Work on the development and industrial adoption of industrial robots
(IR) for various technological purposes is being conducted on a wide scale
in Poland. IR of the PRO 30 and PRO 80 models, intended primarily for milling
machine charging, are shown in Figure 1. They are stationary robots, instal-
led on a turntable.

Technical Specifications

Model of IR	PRO 30	PRO 80
Lifting capacity, kg:		
at top speed	30	80
at 30% top speed	60	120
Positioning precision, mm	±0.4	±0.4
Rotation angle, deg:		
around vertical axis	300	300
shoulder	65	60
elbow	62	--
Rotation speed, deg/s:		
around vertical axis	60	34
shoulder	60	20
elbow	60	--

These robots operate in an angle coordinate system and have a double grip,
by virtue of which their productivity during the servicing of machines is
increased.

The limbs of IR (except for the grips) are driven by high-torque DC motors
(of the type manufactured by the Porter firm of the United States) of the
5680 series. Polish industry is presently adopting the manufacture of elec-
tric motors with a printed circuit board armature for these models of robots.
Motion is transferred from the motors to the final controls of IR through
flat-tooth belt transmissions and screw-nut ball joints.

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A ChPU [not further identified], model NUMS406P, which provides control of
six degrees of mobility, was developed for controlling PRO robots. The
memory units of the system are recorded on floppy discs. The movements of
a robot are programmed by teaching with memorization. The rate of movement
in terms of each of the controlled coordinates is set independently. Memory
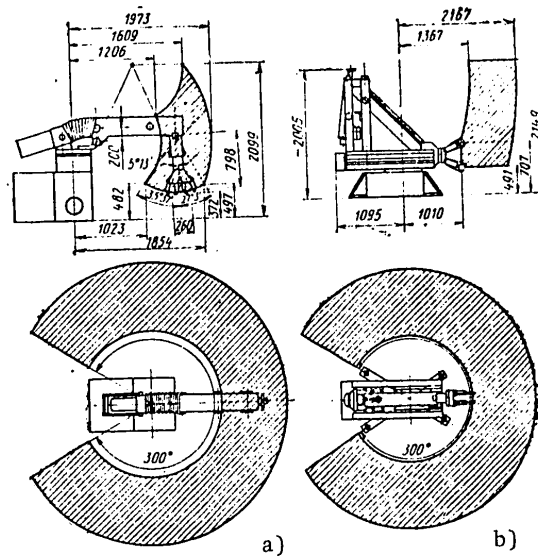capacity is 6K bytes.

Figure 1. Models PRO 30 (a) and PRO 80 (b) industrial
robots.

Work on the development of the unit design system for prototype IR is under
way. The following series of IR by lifting capacity was selected for this
project: 30 (60); 80 (160); 160 (315); 315 (630); 630 (1,000) kg. Lifting
capacity at reduced speed is enclosed in parentheses.

Models RIMP 400 (Figure 2) and RIMP 600 IR have been developed for servicing
foundry equipment and the RIMP 1000 model was developed for welding operations.
The RIMP 400 IR is designed on the principle of the famous Japanese robot
Aida and consists of a stand and a rotating column. It can have one or two
arms. The control panel is mounted on the stand, but it can be installed in
a separate side-by-side unit if need be. Drive is pneumatic with hydraulic
dampers for braking. The programming system is designed as a keyboard and
provides communications between the robot and machinery to be serviced.

The RIMP 1000 robot is designed on the principle of the Unimate robot
(United States). It consists of a base with a rotating column and a tele-
scoping extensible arm, in which there is fastened a head that supports

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either a gripping device, or a special mechanism (for example, a welding torch). The drive is servohydraulic (hydraulic cylinders). The robot control system is designed as a separate cabinet, which can be set up in a convenient place.
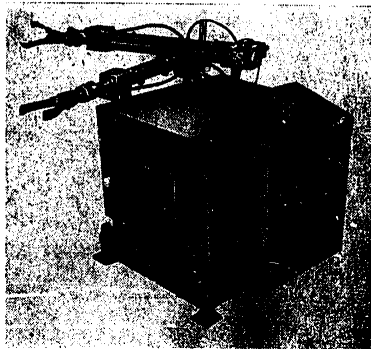

Figure 2. Model RIMP 400 industrial robot.

Technical Specifications

Model of IR	RIMP 400	RIMP 600	RIMP 1000
Number of degrees of mobility	4	4	3-6
Maximum lifting capacity, kg	5	4	60
Positioning precision, mm	±0.3	±0.3	±1.5
Stroke of arm, mm:			
horizontal	400	600	800
vertical	100 (150)	100 (150)	--
Arm speed, mm/s:			
horizontal	1,000	1,000	750
vertical	500	500	--
Angle, deg:			
rotation around vertical axis	120	120	110
tilting of head	--	--	200
Speed, deg/s:			
rotation of arm around vertical axis	120	120	±110
rolling of arm around horizontal axis	--	--	57
tilting of head	--	--	110

The Polish electrical engineering association developed the PR-02 modular unit system, whereby robots can be assembled with various numbers of degrees of mobility, i.e., modifications that meet the needs of clients.

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Technical Specifications

Number of degrees of mobility	2-7
Maximum lifting capacity, kg	6
Positioning precision, mm	±0.5
Stroke of arm, mm:	
horizontal	600
vertical	50 (400)
Arm speed, mm/s:	
horizontal	300-500
vertical	300-350
Angle of rotation around vertical axis, deg	360
Rotation speed, deg/s	180
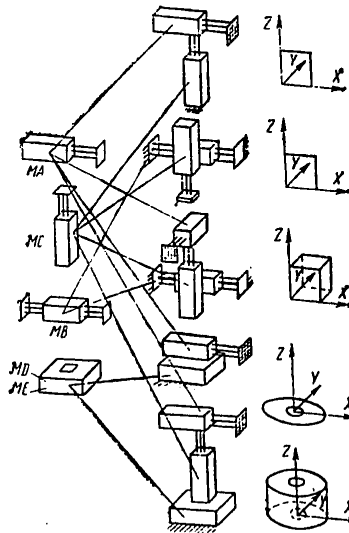
Figure 3. Modules of PR-02 system.

The PR-02 system contains pneumatically driven modules, which produce linear and angular motions. Three types (MA, MB, MC) of modules (Figure 3) produce linear motion; two types of modules produce rotation of the head hinge, where the gripping device is fastened (ME), and of the body (MD). All types of modules have two stops, with the exception of the MD, which has three stops with a maximum stroke of 360 mm.

The strokes, controlled by mechanical stops, are: 50, 300 and 600 mm for the MA module; 20, 200, 400 and 600 mm for the MB module; 32 and 50 mm for

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the MC module; 300 and 360° for the MD module; 180 and 360° for the ME module. The control system is designed as a separate panel, which can be installed at any distance from the robot, up to 10 m from the final control mechanism. The panel has a 640-jack diode matrix, several groups of push-buttons and signal lights that indicate the progress of the program.

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METALWORKING EQUIPMENT

NEW HEAVY PLANO-MILLING MACHINE

Moscow STANKI I INSTRUMENT in Russian No 10, Oct 79 p 27

[Article by Ye. S. Artyukhov, A. D. Gerasimov and G. N. Limarenko: "Hydrostatically Lubricated Worm-Rack Transmission of Plano-Milling Machine with ChPU"]

[Text] The Minsk machine building industrial association has designed and built a heavy plano-milling machine with a contour ChPU [not further identified] system (the main drive motor power is 30 kW). This machine incorporates closed hydrostatic guides (with floating seats on constricted plates with power through valves in the vertical plane, and with power from diaphragm regulators in the horizontal plane; the calculated hydrostatic gap is 60 micron) in a movable bench and a hydrostatically lubricated worm-rack transmission (ChRP GS), developed in conjunction with ENIMS [Experimental Scientific Research Institute of Metal-Cutting Machine Tools] in the bench feed drive.

Studies have shown that the real parameters of the rigidity of the guides differ from the calculated ones. The oil pressure in the pockets of the horizontal guides (without a load) was identical at 5-6 kg/cm^2 (the calculated pressure is 6.7 kg/cm^2), and in the pockets of the vertical guide (unloaded) it fluctuated within 7-15 kg/cm^2. The static rigidity of the horizontal hydrostatic guides with a load applied in the center of the bench was 450-630 kg/μ, and with a load applied on the ends of the guides of the bench, 135-250 kg/μ. However, the rigidity of the vertical guides with a load applied in the center of the bench is 100-450 kg/μ, and with a load applied on the ends of the guides of the bench it is 40-200 kg/μ.

The bench feed drive is mounted on the frame of the machine. The worm and reducer box are installed on the bottom of the frame, and the worm racks are fastened on the bench. The radial thrust bearings of the worm are two-row roller bearings with cylindrical rollers, with which the worm can be positioned in the thrust bearings with 0-5 μ negative allowance in the radial direction. This minimizes the shifting of the worm relative to the worm racks under a load. The axial thrust bearings of the worm are hydrostatic bearings combined with end boilers.

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This design eliminates the gap in the axial bearings and provides the simplest means of lubrication. The calculated hydrostatic clearances in ChRP GS are 50 μ. To assure high rigidity the worm was made as a one-piece shaft. The worm parameters are: outside diameter 200 mm; thread pitch 30 mm; tooth height 21 mm; 6 turns; profile half-angle 7°30'. The small profile angle was selected because the smaller it gets the less radial force there is in the worm-rack engagement, and the load capacity of the transmission increases.

On each side of a thread (in one revolution) there are 16 pockets, connected by holes with the ends of the worm. The pockets on the right hand side of the thread are connected to the left end of the worm, and the pockets on the left hand side of the thread are connected to the right end of the worm. This arrangement of pockets and holes increases the rigidity of an end-lubricated transmission.

An analysis of possible transmission manufacture and assembly errors shows that the profile mismatch of the teeth of the racks and worm threads should not exceed 10-15 μ, and the pitch error should not exceed 20-25 μ. This precision can be achieved by machining the working worm and master worm with the thread-cutting machine in the same setup. The thread profile of the master worm is identical to that of the working worm; thread thickness of the former is greater than that of the latter by the overall clearance in the transmission; the master worm has the same length as the worm rack.

The teeth of the worm racks (steel or iron) are made in accordance with the following technological procedure. During rough machining the teeth are cut with a clearance of 1-1.5 mm on each side (in relation to the working surfaces of the threads of the master worm), the base surfaces of the racks, which are used during subsequent technological operations (including assembly of the racks on the bench), are machined with adequate precision. Then a 1-1.5 mm thick polymer film is applied on the rack tooth profile with the aid of an accessory, in which the master worm is installed. After the polymer film hardens (at room temperature for 12-24 hours) the master worm is easily separated from the rack, since a separating agent is applied on the threads of the master worm before shaping.

Tests on stands and on a machine disclosed that the described technology provides high transmission manufacture precision and greater load capacity, and the polymer film on the rack teeth provides additional strength. During adjustment of the machine the transmission was subjected to overloads and operated for some time in a composite friction mode. An inspection after the tests did not reveal any visible changes of the polymer film on the rack teeth.

The actual oil flow rate was 14-15.5 dm^3/min. The maximum load on the transmission (5,100 kg) was determined by thread-cutting conditions; the maximum idle speed of the bench is 7,500 mm/min. It is important to note that oil pressure in the pockets began to drop at 6,000 mm/min.

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The deviation of the movement of the bench along the guides of the machine from straight-line changed with the passage of time (due to thermal deformations of mated parts of bearing structures of the machine, including the bench) and exceeded tolerances.

Studies disclosed that the basic sources of heating of the oil are the ChRP GS and the valves in the hydrostatic guide power system. A model KhMSOZh-4 cooling system was built into the lubrication system of the machine for stabilizing the oil temperature (within 1-3°C), with the result that the limiting deviations of the movement of the bench from straight-line did not exceed 0.007 mm through the entire length of the guides of the frame.

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METALWORKING EQUIPMENT

SELF-ADJUSTING CONTROL SYSTEMS OF MACHINE TOOLS WITH PROGRAM CORRECTION

Moscow STANKI I INSTRUMENT in Russian No 7, Jul 79 pp 15-17

[Article by A. Ye. Kobrinskiy and N. A. Serkov]

[Text] A self-adjusting system (AS) for controlling milling machines is based on the principle of correction of the original program in consideration of information accumulated during processing of one or several parts of a lot.

Experimental investigations [1] have shown that in effective algorithms of the calculation of programs a self-adjusting process, even during the processing of complicated surfaces, converges quite quickly, and two or three cycles of adaptation are sufficient to eliminate most of the systematic components from the processing error.

Systematic processing errors change in time. But with AS it is possible in any time interval of a technological process to include self-adjusting cycles. By measuring some i-th part of a lot it is possible to judge how well the control program satisfies technological conditions, established as a result of processing of several previous parts and, if necessary, to correct the program for the processing of the next part. This eliminates the "drift" of systematic errors that occurs as time passes. This is how the most important property of AS -- improvement of machining precision without strengthening requirements on the precision of the machinery -- is realized.

The principles of AS with measurement of machine parts by a system, built directly in the milling machine, were applied for the first time for milling blades in machines with ChPU [not further identified] [1]. A part was pre-processed by an original program. Then the operator moved it to the measurement position, where he determined machining errors. The control programs were corrected in consideration of these errors for milling the next part. In this semiautomatic mode the correction system was used for adaptation "from part to part" and "from pass to pass."

Extensive experimental investigations disclosed that the method of self-adjustment of control programs increases blade milling precision by a

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factor of 3-4 [1]. The distribution of errors during the machining of a lot of blades in accordance with an original program (curve 1) and for machining with "part to part" self-adjustment (curve 2) is shown in Figure 1.
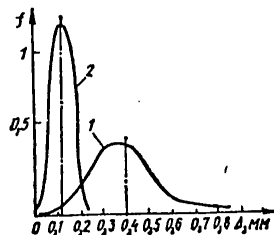

Figure 1. Distribution of errors of machining by original program (curve 1) and with "part to part" self-adjustment (curve 2) of lot of blades: Δ -- machining error; f -- probability density.

Combining the technological and measurement positions is an extremely effective approach to machining of large nonrigid parts with AS. Measurement directly in the milling machine does not require additional operations connected with the transportation and mounting of a part to be machined.

The capabilities of AS can be used more completely in coordinate measuring machines. These machines feature high precision and productivity (in the automatic mode) of measurements and processing of information obtained as a result of these measurements.

AS is being developed at the present time in two directions: 1) toward expansion of the range of application (examples of the effective utilization of the above-described methods of adaptation in lathes, grinding, multitool and other machines and in traditional types of machines and machines with ChPU are already known); 2) toward elevation of the level of automation of adaptation procedures, all the way to the automation of the entire process of adaptive control on the basis of electronic computers.

It is advantageous to use AS in semifinishing and finishing operations, where systematic factors, which change in time (machine adjustment errors, intrinsic geometric errors of a machine, thermal deformations of the SPID [not further identified] system, dimensional wear of tools, etc.), as a rule, exert the dominant influence on machine precision. In cases when machining precision is affected to a great extent by random factors, the technological process must be perfected, for example by using adaptive systems to stabilize or eliminate these factors.

Examples of the application of different versions of AS are described below. AS of operational correction [2] (Figure 2) is intended for correcting the cumulative circular step error during the grinding of gear wheels in models 5851 and 5853 machines. The cumulative circular step error of the first machined gear of a lot is measured with an instrument mounted on the machine. The operator, on the basis of measurement results, determines the correction factor and the number of teeth in which it must be introduced and selects a correction program on the control panel. The correction program is automatically worked out (the correction factors are incorporated in the movement) during the grinding of the next gear wheel. If need be the

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self-adjustment process is repeated. The use of an operational correction system during the grinding of gears reduces the cumulative circular step error by a factor of 2 [2].

A self-adjusting correction system with an extra master [3, 4] is intended for a profile milling machine of the traditional type. A schematic diagram of this type of system is presented in Figure 3 [4]. It includes main master 1, which carries information about the shape of a shaft to be machined, and extra master 2, which is the first machined part.

The trajectory of tool 3 relative to machined part 4 is corrected for the machining error of the first part. This system is effective for machining, for instance, nonrigid medium-size shafts in the model VT-11 automatic hydraulic profiling mill (the error in the longitudinal cross section of a shaft is reduced by a factor of 4-6 [5]).
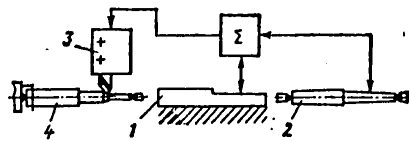

Figure 3. Diagram of self-adjusting correction
system with extra master for profiling lathe.

AS have been developed recently for machines with ChPU. A characteristic feature of these AS is the fact that the measuring instrument is built into the machine, and the adaptive unit is built in the ChPU system. This type of adaptive system can be used for the model PN lathe with ChPU, built by the Boehringer firm (FRG) (Figure 4a), equipped with a measuring system (Figure 4b) and a Diacont correction unit of the Dr. Perthen firm (FRG) [6]. The system automatically (on the basis of results of measurement of a machined part) introduces three corrections (two for the outside diameter and one for the inside diameter).

The operator can also correct other dimensions that are not covered by the adaptive system. The correction step is 0.002 mm. Based on data of the Boehringer firm, the use of AS increases milling precision by one class.

The results of tests [7] of an adaptive system for boring holes in a lot of parts in a milling machine with ChPU are presented in Figure 5. The operating algorithm of the correction system was so constructed that measurements were taken after every machining cycle, and the correction factor (for the size of the tool) was changed only if the machining error swung beyond signal boundary S (±2.5 μ in this example); the weight coefficient for taking into account the measurement error in the correction factor was 1.

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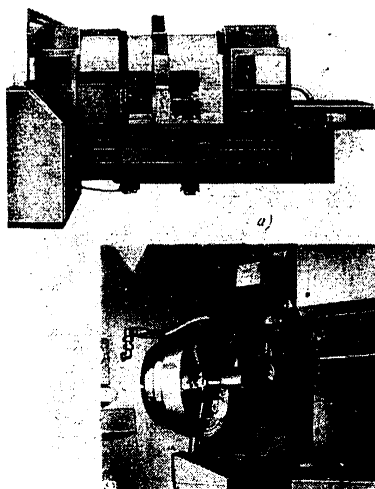
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Figure 4. Model PN lathe with
ChPU (a) and measurement system
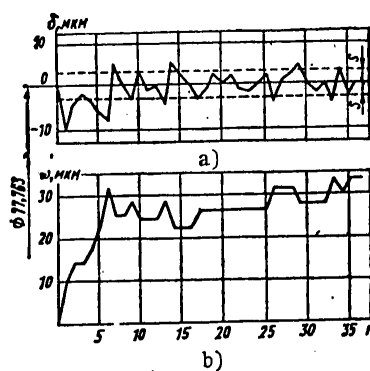in working zone of machine (b).

Figure 5. Results of machining of lot of parts:
a -- corrected error δ of machining of diameter
(diameter 77, 763 mm, n -- number of part in lot);
b -- correction factor ω. [мкм=micron]

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The Crenfield firm (Great Britain) manufactures a machine (Figure 6) for grinding cams. This machine is equipped with a measuring system and AS with program correction [8]. Measurement system 2 and grinding wheel 6 are installed on opposite sides of cam 1. Before the grinding process begins information R' = R'(θ) about a given cam profile is fed into a computer (θ is the angle of rotation of the cam). During the first pass the final control of the machine (drive 5) is adjusted by this program. As soon as the profile part of the cam reaches the measurement position the measurement system is turned on and information about the actual radius vector R as a function of angle θ goes from transducers 3 and 4 into the computer. In the second and subsequent passes the cams are ground by corrected programs. The machine is designed for precision milling of a profile (±2 μ error). The correction system is used for "pass to pass" self-adjustment.

It is important to note that in this AS measurement lags behind milling by only one-half a pass. Consequently the technological utilization factor of the machine does not depend on the adaptation procedure.

AS with program correction are also used in automated industrial complexes and shops. Technological machinery operates in the automatic cycle in combination with transport and measurement systems.

This kind of AS is used in an automated complex of milling machines with ChPU (GDR) [9] (Figure 7a). The technological chain of machines C6-C7-C4-C5-C3 with ChPU, intended for rough machining and finishing, and of machines C1 and C2, intended for finish machining only, include three measurement instruments M1, M2, M3. The technological and auxiliary machinery is controlled by two computers, and machined parts are transported by a pneumatic conveyor.
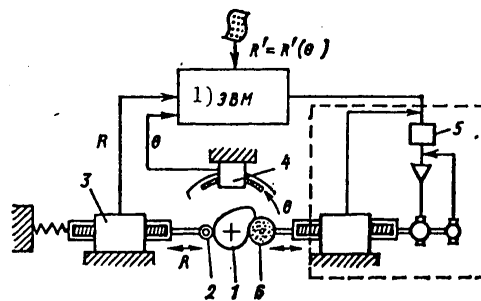

Figure 6. Diagram of Crenfield grinding machine with self-adjusting control system and measurement system.
KEY: 1. Computer

Machine M1 measures one after the other blanks that come from satellite charging position 3 and determines the tolerance to an accuracy of ±0.5 mm.

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This information goes into the computer, which determines the necessary number of rough passes. Machines M2 and M3 measure the machined parts to an accuracy of 0.005 mm. The measurement results go into the computer and are taken into account during control of the machines during finishing operations. Machine M2 measures the finished parts until they leave the machine shop. A certificate is written up on the basis of the measurement results.
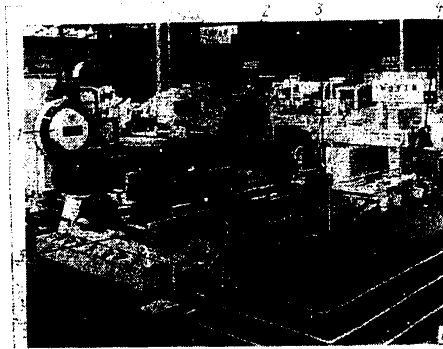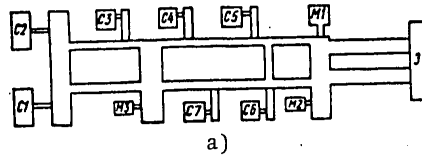

a)

Figure 7. Diagram of machine shop with Prisma
ChPU (a) and general view of machine shop with
ChPU of the Shin Nippon Koki, Ltd. firm (b).

A general view of a shop, similar to the one described above and manufactured by the Shin Nippon Koki, Ltd. firm (Japan) [10], is presented in Figure 7b. Two multitool machines 1 and 2 are connected to cleaning machine 3 and measuring machine 4 by conveyor 5. The DNC ChPU system performs direct automatic correction of machine data on the basis of results of measurement of the finished parts. The shop operates on a two or three shift basis and employees work one shift.

Machine shops of the Sundstrand Machine Tool and Caterpillar Tractor firms (United States) [11], incorporating ChPU, include a measuring machine of the DEA firm (Italy) of the Gamma B model. During the machining process a part goes to the measuring position up to seven times. The measurement frequency is selected such as to assure a given quality.

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The Boehringer firm developed an automated lathe complex, which has been in operation for 1 year [12]. This complex combines a lathe, an industrial robot, automatic rod loader and a measuring system. ENIMS [Experimental Scientific Research Institute of Metal-Cutting Machine Tools] is conducting similar work on the development of automated machining complexes with AS [13].

It is important to note that the capabilities of AS with program correction are by no means exhausted. Greater use should be made of "pass to pass" adaptation for increasing the machining precision of the first part of a lot. The parameters of the correction algorithm (signal boundary and weight coefficient) should be optimized with the utilization of the digital modeling method [14].

The following may be used as the criterion of optimization: 1) attainment of the maximum machining precision for operations of special precision; 2) attainment of a given precision with the minimum necessary number of measurements (minimum down time of technological machinery); 3) attainment of maximum machining precision of parts with complex surfaces in an intermediate operation for the purpose of substantially increasing productivity during a subsequent time-consuming finishing operation.

It is very important to develop a mathematical model of the correction process for the purpose of selecting the optimum parameters of an algorithm. Such a model should take into account the probability properties of the process whereby parts go into machining and measurement in a multifunctional machine shop with a DNC type of ChPU.

Further development of self-adjusting machine control systems with program correction will make it possible to utilize more completely and more effectively the capabilities of computer technology and programmable control for complete automation of machining processes and to improve the precision and productivity of machinery.

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METALWORKING EQUIPMENT

AUTOMATIC TOOL REPLACEMENT SYSTEM FOR HEAVY PLANO-MILLING MACHINE

Moscow STANKI I INSTRUMENT in Russian No 10, Oct 79 pp 6-7

[Article by S. Ya. Fel'dman]

[Text] The model 6620MF4 heavy plano-milling machine with ChPU [not further identified] and an automatic tool replacement system, designed by the Ul'yanovsk GSKB [State special design office] of heavy milling machines, has been built at the Ul'yanovsk heavy and unique machine factory (Figure 1). The machine is designed for milling, drilling, boring and threading during the machining of rectilinear and curvilinear surfaces of parts weighing up to 30 tons; bench dimensions are 2,000 × 4,000 mm.
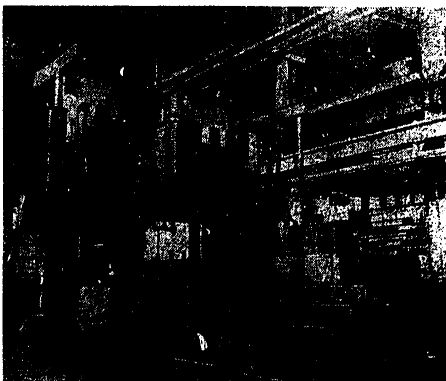

Figure 1. Model 6620MF4 heavy plano-milling machine with ChPu.

A model N55-2 ChPU contour-position system features high machining precision with positioning and machining of curvilinear contours controlled by a

interpolator. With a set of 40 tools and automatic tool replacement system (Figure 2) it is possible to machine parts with high productivity.

Cross-bar 6 with guides 5, along which move headstock 7 and carriage 12 with vertical guides 17 for tool holder 11, is fastened to posts 1. Body 23 of the tool box, in which is installed rotating drum 24 with sockets for tool mandrels 22, and which moves in the axial direction, is installed on column 25.

Rod 21 of hydraulic cylinder 18 is rigidly connected to body 23. To the moving body of the latter is fastened lock 20 (in the form of a fork), which interacts with head 19 of carriage 12 in its extreme left position. At the top of carriage 12 are mounted cams 15 and 13, which interacts (in the extreme positions) with end switches -- 14, 16 and 10, 9, respectively, installed on cross-bar 6 and on headstock 7. To holder 11 is fastened yoke 27, into which roller 30 is inserted on the axis. On the back side of carriage 12 is fastened boss 26, which engages with a link of chain 29.

On the right end of cross-bar 6 is fastened drive 2, which moves carriage 12. Motor 4 of the drive is connected to sprocket 3 of chain 29 through worm set 36, safety ball clutch 37 and electromagnetic clutch 38. Manipulator 8, with mechanical double-lock handle 28, capable of rotation and axial movement, is fastened on the left end of headstock 7.

In the body of the manipulator is installed hydraulic cylinder 32, drive rod 31 of which, in the bottom position, interacts through a wedge with roller 30 when carriage 12 and manipulator 8 come into contact. In the top position the rod interacts with end switch 35 (through cam 33) and with end switch 34 (with the top end).

The system operates as follows. With carriage 12 in the initial position tool holder 11 is in contact with manipulator 8, the mechanical handle of which is in the top position. On command from the ChPU system to replace a tool (with end switch 35 depressed) the mechanical handle is turned 75° to the mandrel locking position with tools in the arbor and in holder 11. After the mandrel is released with a tool in the arbor the mechanical arm is lowered, withdrawing the mandrel from the arbor and from tool holder 11.

Then the mechanical handle is turned 180° and raised, inserting the mandrel with a new tool in the arbor, and the mandrel with the worn out tool is inserted in tool holder 11. After the mandrel with the tool in the arbor is tightened the mechanical handle is returned to the initial position. The part begins to be machined with the new tool.

The ChPU system sends a command to separate carriage 12 and the manipulator. Then rod 31 rises, releasing yoke 27, and interacts with end switch 35 through cam 33. The top end of the rod strikes end switch 34, which turns on motor 4 of drive 2 and engages electromagnetic clutch 38. The latter connects drive 2 with sprocket 3.
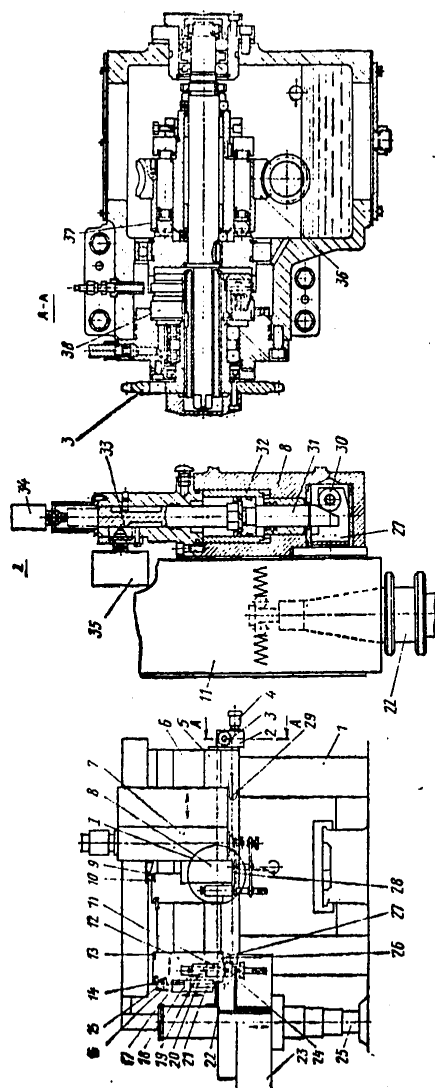
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Figure 2. Automatic tool replacement system, installed on model 6620MF4 machine with ChPU.

Chain 29, through boss 26, shifts carriage 12 to the tool box. When the carriage reaches the box cam 15 applies pressure to end switch 14, which switches motor 4 to the braking mode. Then cam 15 depresses precision motor shutoff end switch 16. Head 19 is engaged with lock 20, and mandrel 22 with the worn-out tool is inserted in the socket of drum 24.

After the carriage is stopped oil is forced under pressure into the piston cavity of hydraulic cylinder 18, which along with lock 20 and tool holder 11 moves up along guides 17 of carriage 12. While that is happening mandrel 22, which remains in the socket of drum 24, is released in tool holder 11.

Then drum 24 begins to rotate. When the desired tool is placed in the charging position oil is forced into the rod cavity of hydraulic cylinder 18, and tool holder 11, as it moves downward, grasps the shank of the mandrel of the new tool.

The ChPU system sends a command to turn on motor 4 and electromagnetic clutch 38, with the result that carriage 12 moves toward the headstock. When the carriage reaches it cam 13 depresses end switch 10, switching motor 4 to the braking mode. Then cam 13 depresses precision stop switch 9 of motor 4.

Rod 31, as it moves downward, strikes roller 30 with its wedge surface and pulls carriage 12 toward the manipulator. Now the carriage, manipulator and headstock travel along guides 5 of the cross-bar as a single unit; during this time electromagnetic coupling 38 is disengaged, and therefore as chain 29 moves sprocket 3 idles. The new tool is in the starting position.

The tool replacement time (time necessary for moving a tool to the tool box, searching for the desired tool and moving it to the manipulator) is 27 s and is combined with the machine milling time.

The described automatic tool replacement design keeps the headstock in a constant position relative to a machine part during tool replacement, which improves milling precision.

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